grasses

Article

A Comparison of Biomass Production and Quality of Congo and Rhodes Grasses in Nigeria

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Abstract

The yield and quality of biomass produced in a growing season determine feed allocation, livestock performance, and system capacity and resilience. Congo grass (*Urochloa ruziziensis*, UR) and Rhodes grass (*Chloris gayana*, CG) are important grass species for livestock in Sub-Saharan Africa, where their high yield potential and adaptability provide leverage to mitigate persistent feed gaps. This study investigated the morphological traits, biomass yield, and nutritive value of UR and CG in the Northern Guinea Savanna of Nigeria over three years (2019–2021) to assess their biomass yield and quality responses to successive harvests. We hypothesised that UR would outperform CG in yield and quality over the study period. Grasses were established in 2019, with multiple harvests annually from four replicate plots per species. UR consistently produced more tillers and leaves per tussock and achieved significantly higher biomass and crude protein (CP) yields at each harvest ($p < 0.001$), averaging 32.2% and 38.4% greater biomass and CP, respectively, compared to CG. Nutritional analysis revealed that CG contained 19.4% less CP, 23.4% less metabolisable energy, and 22.7% less ash than UR, while having higher fibre fractions ($p < 0.001$). Overall, UR demonstrated superior productivity and nutritional value under the tested conditions, highlighting its potential as a more reliable forage option for farmers in the Northern Guinea Savanna of Nigeria.

Keywords: yield; harvest; morphological characters; nutrient contents; *Chloris gayana*; *Urochloa ruziziensis*

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1. Introduction

Livestock products are in high demand in Sub-Saharan Africa (SSA), driven by population growth, improved living conditions, urbanisation, and nutritional value [1]. However, meeting this rising demand requires the overcoming of challenges, including insecurity, climate change, and widespread low-productivity lands. The pronounced seasonality of the region further exacerbates these constraints by creating nutritional feed gaps between the wet and dry seasons, reducing forage availability and nutritive value needed to sustain livestock health and productivity [2]. In many parts of SSA, herders depend heavily on poor-quality forages from natural rangelands that have not been reseeded, fertilised, or systematically managed for productivity [3]. For example, in Nigeria alone, livestock graze an estimated 34.1 million hectares of natural grassland [4], highlighting both the vast extent of unimproved pastures and the urgent need to enhance their management through the introduction of improved forage species. Such natural pastures are often inadequate in quality and quantity, contributing to low animal performance. Forage plant breeding offers a pathway to address these challenges by developing cultivars that enhance agricultural productivity through increased annual biomass yield, persistence of perennial species, and improved nutrition for livestock [5]. Tropical forage breeding, which gained momentum in the mid-20th century [6], has achieved notable success with grasses such as *Urochloa*, *Cenchrus*, *Megathyrsus*, and *Chloris*, now widely cultivated in tropical and subtropical regions [7].

The grass genus of *Urochloa* is widely distributed across tropical and subtropical regions, including West-Central Africa, Western India, Southeast Asia, and the Pacific [7,8]. *Urochloa ruziziensis* (R. Germ. & C.M. Evrard, Crins) (UR) originates from Ruzizi Valley in eastern Democratic Republic of the Congo, Rwanda, and Burundi [9]. The grass is well adapted to cut-and-carry systems with harvest intervals of about eight weeks [10] and can tolerate periods of moderate to heavy grazing [11]. Reported biomass yields of UR exceed 20 t DM/ha in Australia and South America and up to 25 t DM/ha in Sri Lanka with the application of 366 kg N/ha fertiliser [12]. In terms of nutritional value, UR is highly suited for ruminant feeding. Santana et al. [13] reported crude protein (CP) of 97 g/kg DM, neutral detergent fibre (NDF) of 581 g/kg DM, and in vitro digestible dry matter digestibility (IVDM) of 76.2%.

Chloris gayana Kunth (L. 't Mannetje & S.M.M. Kersten) (CG) is a perennial species native to Africa and recognised as one of the most important warm-season forage grasses in subtropical and tropical regions worldwide [14]. Due to climate change, it is increasingly being introduced into temperate zones where rising minimum temperatures and winters are less severe, enhancing adaptability in temperate climates [15]. The grass is noted for its persistence, drought tolerance, and high productivity [16]. According to Murphy [17], it can yield up to 30 t DM/ha, with yields ranging between 10 and 16 t DM/ha. The nutritional composition of CG is highly variable and strongly influenced by environmental conditions. In Australia, Jayasinghe et al. [18] reported that whole-plant samples contained CP of 124 g/kg DM, NDF of 641 g/kg DM, IVDMD of 729 g/kg DM, and IVDNDF of 589 g/kg DM, along with ME of 8.9 MJ/kg DM. Daba et al. [19] observed CP concentrations ranging from 35 to 61 g/kg DM and NDF values between 672 and 709 g/kg DM.

Understanding the biomass yield obtained from successive harvests during the growing season is essential for planning feeding budgets and for optimising herd sizes over time [20,21]. This is particularly critical in Nigeria, where ruminant livestock populations are projected to reach 207.8 million goats, 78.2 million sheep, and 53.6 million cattle by 2050 [22], requiring proper management to meet the protein need of a projected 398 million people with the same period [23]. Meeting this demand will depend heavily on the availability of high-yielding and quality forages. Although comparative studies on tropical forage grasses have been conducted elsewhere, little is known about the performance of UR and CG under Nigeria's specific conditions, characterised by low-input smallholder systems, variable rainfall, long dry seasons, and reliance on unimproved rangelands. This research represents one of the first systematic on-station evaluations of UR and CG in the elevated, cool tropical climate of the Northern Guinea Savanna. Using cut-and-carry management practices relevant to local farmers, the study was designed to generate context-specific data on biomass yield, persistence, and nutritional value. Addressing this knowledge gap is critical for guiding the promotion of improved grasses across Nigeria's diverse agroecological zones. With ruminant populations and feed demand expected to rise sharply by 2050, the results from the study are intended to support climate-smart livestock production by identifying resilient, high-quality forage options that reduce seasonal feed gaps, improve productivity, and enable scaling across similar agroecological regions. By evaluating UR, widely studied in Central and East Africa and South America, alongside CG, which is broadly adopted across Africa but under-characterised in Nigeria, this study provides comparative evidence to inform species selection and foster adoption among smallholder farmers.

The on-station trial, conducted in the elevated, cool tropical environment of Jos in the Northern Guinea Savanna, assessed the performance of UR and CG under cut-and-carry management by measuring their morphological traits, biomass yield, and nutritive value. The cut-and-carry system was selected because it reflects common smallholder practices in Nigeria, where forages are harvested and fed to tethered animals during the rainy season, when croplands dominate, and serve as vital supplements in the dry season, when livestock depend on crop residues and fibrous forages. We hypothesised that UR, with its higher reported CP and lower fibre content, would provide superior forage quality, whereas CG, valued for its persistence and drought tolerance, would demonstrate greater adaptability and stable biomass yields under local climatic conditions. By systematically comparing these two key tropical grasses within the same agroecological setting, this study provides context-specific evidence to support species choice, address seasonal feed gaps, and advance climate-smart livestock production strategies for smallholder farmers in Nigeria.

2. Materials and Methods

2.1. Study Site

The study was carried out at the Federal College of Forestry, Plateau State, Nigeria (Figure 1). The experimental site is located at a high elevation (9°56′44′′ N, 8°53′32′′ E, 1200 m above sea level). The region is characterised by two distinct seasons, a dry and a rainy season. The climate of the area can be classified as a cool tropical climate with temperatures ranging from 15–27 °C during the rainy season and between 7–32 °C during the dry season. Rainfall usually begins between late March and early April, peaks in July and August, and gives way to the dry season, which typically commences in mid-October. Rainfall and air temperature for the study period are presented in Figure 2.

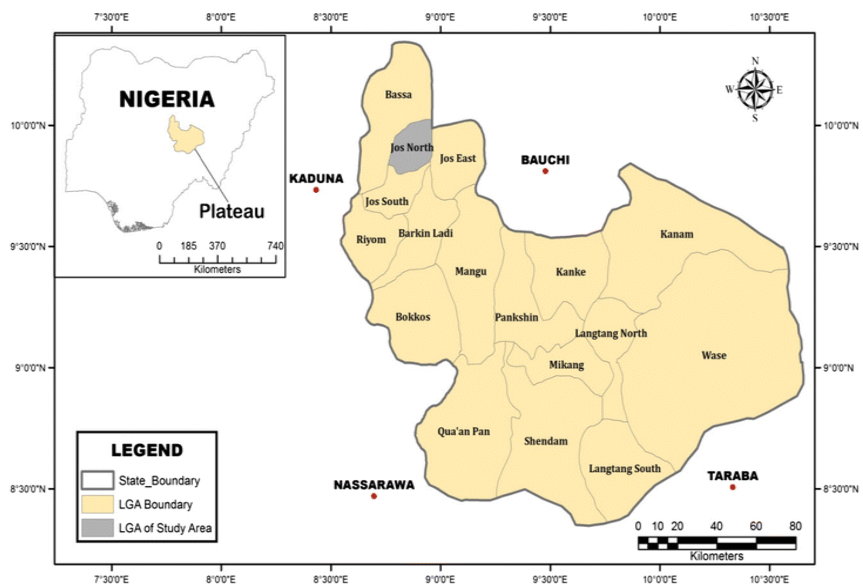

Figure 1. Study site location as shown within Nigeria and Plateau State.

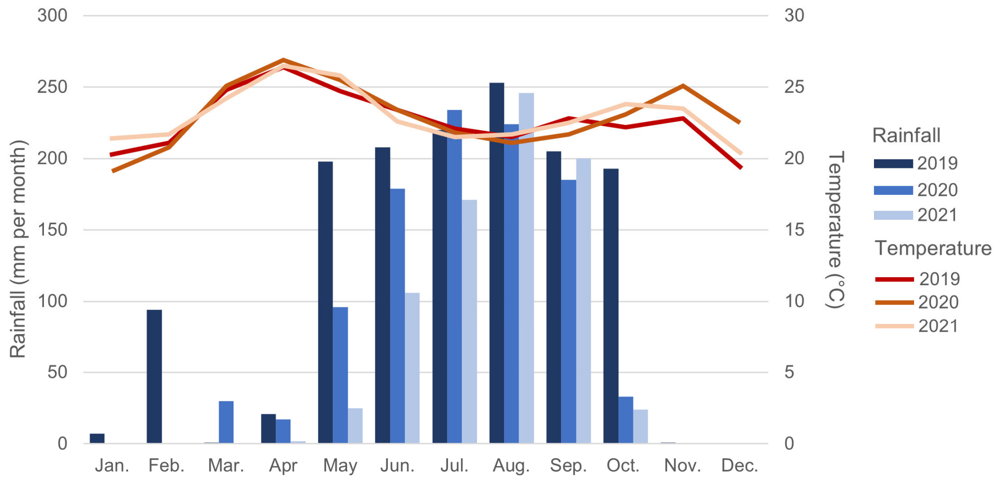

Figure 2. Mean rainfall and temperature patterns for 2019–2021.

Entisols dominate the experimental area, occurring on hill and mountain crests, side slopes, and upper foot slopes [24]. The soils are reddish in colour and support agricultural activities in the region. However, they are characterised by low to deficient total nitrogen (N) status, available phosphorus (P), and calcium (Ca) [24]. Soil analysis from the experimental site indicated low fertility, with 0.43% nitrogen, 2.94% organic matter, and 6.52 mg/L P with a pH of 5.84. These values are consistent with the typical soil conditions of the area.

2.2. Experimental Design and Grass Establishment

Two grass species, *Urochloa ruziziensis* (UR) and *Chloris gayana* (CG) variety Callide, were evaluated between 2019 and 2021 for their morphological characters, dry matter (DM) yields, and nutritional composition for livestock productivity. The field trial was conducted using a randomised complete block design with four plots per species. Each plot measured 3 m × 2 m, with 1 m between plots and a 2 m spacing between blocks. Prior to sowing, the experimental field was ploughed once and harrowed twice to prepare a clean seedbed. On 15 June 2019, seeds of both grasses were sown in rows spaced 50 cm apart and drilled at a depth of 1 cm in a continuous flow. Seeding rates were 7.2 kg/ha for CG and 9.3 kg/ha for UR, adjusted for seed size, weight, and purity following the recommendation of Karki [25]. Fertilisation regimes included an application of single super phosphate (16% P_2O_5) at 30 kg P/ha after tillage in the first year. Nitrogen was applied as granular urea (46% N) fertiliser at 80 kg N/ha in 2019, in the year of establishment, and 120 kg N/ha in both 2020 and 2021 (Table 1).

Table 1. Schedule for fertilisation and harvesting.

Fertiliser/Harvests	Quantity/ Number of Harvests	Year		
		2019	2020	2021
Fertiliser	30 kg P/ha	10 June	-	-
	40 kg N/ha	-	8 May	8 May
	40 kg N/ha	7 July	7 July	7 July
	40 kg N/ha	1 September	1 September	1 September
Harvests	1	-	10 June	10 June
	2	5 August	5 August	5 August
	3	29 September	29 September	29 September

2.3. Biomass Yield Estimation and Morphology Evaluation

Grasses were harvested twice in the year of establishment (2019) and three times in subsequent years (Table 1) to estimate biomass production. Harvests were carried out at eight-week intervals within a growing season, and DM yield was determined for each cut. For each harvest, plants were cut from a 0.7 m × 1 m strip in the middle row of each plot. The harvested materials were oven-dried, and the results extrapolated to estimate total plot yield. Crude protein yield and ME yield were calculated based on the CP and ME contents. Additionally, at each harvest, ten plants (subsamples with plots) were randomly collected from the middle row to assess morphological traits. The number of tillers per tussock (NTPT) and the number of leaves per tussock (NLPT) were recorded. Here, NTPT refers to the shoots emerging from the plant base, whereas NLPT denotes the leaves that develop on those tillers.

2.4. Analyses of Nutrient Concentration

Samples from each harvest were oven-dried at 55 °C to a constant weight (≈3 days) and ground to pass through a 1 mm. Crude protein was determined using the Kjeldahl method 954.0–1954 [26]. Applying a nitrogen-to-protein conversion with a factor of 6.25. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed by hot detergent digestion following Van Soest et al. [27]. Ash content was measured by loss on ignition at 600 °C for 4 h (AOAC 942.05) [28]. Calcium (Ca) and phosphorus (P) were determined using atomic absorption spectrophotometry of AOAC [29]. Metabolisable energy (ME, MJ/kg DM) was estimated using the predictive equations by Chen et al. [30]: ME = 46.93 − 0.52 × NDF (%).

2.5. Statistical Analysis

A repeated measures analysis of variance (RM-ANOVA) was conducted to assess the main and interaction effects of species, harvest, and year on differences in morphological characteristics, yield, and nutrient concentrations between the two grass species. Species, harvest, and year were treated as fixed effects, including all possible two-way and three-way interactions (Species × Harvest, Species × Year, Harvest × Year, and Species × Harvest × Year). Year was treated as a repeated measure with plots as a random effect. Model residuals were tested for normality using the Shapiro–Wilk test with Bonferroni adjustment, which indicated statistically significant departures from normality for ADF, Ca, and P; however, Q-Q plots suggested the residuals were reasonably close to normal, and Levene's tests confirmed homogeneity of variances. Given these results and the robustness of ANOVA to mild normality violations, the use of ANOVA is considered appropriate for these variables.

All analyses were performed in R Studio [31] running R (4.3.2), and significant differences between means were declared at $\alpha < 0.05$ and means separated using the Tukey post hoc test were appropriate.

The model structure is given below:

$$Y_{ijkm} = \mu + S_i + H_j + Y_k + (S \times H)_{ij} + (S \times Y)_{ik} + (H \times Y)_{jk} + (S \times H \times Y)_{ijk} + \text{Subject}_m + \varepsilon_{\text{ijkm}}$$

where

Y_{ijkm} = observation for species i, harvest j, year k, replicate/subject m;
μ = overall mean;
S_i = effect of species i;
H_j = effect of harvest j;
Y_k = effect of year k (repeated);

$(S \times H)_{ij}$, $(S \times Y)_{ik}$, $(H \times Y)_{jk}$, $(S \times H \times Y)_{ijk}$ = interaction terms;
$Subject_m$ = random effect for experimental unit (plot) across years (to model repeated measures);
ε_{ijkm} = residual error.

3. Results

The results of RM-ANOVA for main effects and interactions are presented in Table 2. The main effect of species was highly significant ($p < 0.001$) for all the variables except for Ca concentration. Harvest effects were associated with significant differences for biomass yield, ME yield, ME, CP, NDF, ADF, ash, Ca, and P concentrations for the main effect of harvest. Significant year × species interactions were detected for ME, CP, NDF, ADF, and P. Year × harvest interaction was significant for biomass yield, CP yield, ME yield, and NLPT, while species × harvest interaction significantly influenced ME, CP, ADF, and P. A three-way interaction (year × species × harvest) was observed only for ME concentration ($p = 0.040$).

Table 2. Repeated measure ANOVA results comparing plant productivity, morphological, and nutritional characteristics across grass species, harvest, year, and interactions.

Variables		Species		Harvest		Year × Species		Year × Harvest		Species × Harvest		Year × Species × Harvest	
		F	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Morphological characters and yields	NTPT	171.9	<0.001	4.0	0.051	0.1	0.822	1.7	0.202	1.8	0.200	0.0	0.862
	NLPT	482.8	<0.001	0.6	0.436	0.6	0.456	4.4	0.040	0.1	0.825	1.6	0.208
	Biomass yield	44.7	<0.001	19.2	<0.001	0.3	0.600	4.2	0.045	0.0	0.872	0.2	0.666
	CP yield	104.9	<0.001	0.7	0.403	3.4	0.068	4.7	0.034	2.8	0.099	0.2	0.650
	ME yield	98.6	<0.001	7.8	0.007	0.0	0.969	5.1	0.027	0.0	0.915	0.0	0.993
Nutrient concentrations	CP	442.6	<0.001	492.6	<0.001	40.8	<0.001	0.1	0.819	87.7	<0.001	0.0	0.914
	NDF	863.2	<0.001	111.6	<0.001	10.9	0.002	2.1	0.156	0.6	0.432	0.0	0.947
	ADF	318.2	<0.001	201.1	<0.001	4.3	0.043	1.7	0.197	58.2	<0.001	0.5	0.565
	Ash	421.2	<0.001	55.9	<0.001	1.3	0.256	0.9	0.339	4.5	0.038	1.8	0.181
	Ca	2.1	0.157	78.0	<0.001	1.9	0.169	1.0	0.334	0.7	0.393	3.6	0.063
	P	144.1	<0.001	29.4	<0.001	10.4	0.002	0.1	0.758	20.5	<0.001	0.1	0.801

Abbreviations: CP, crude protein; ME, metabolisable energy; NTPT, number of tillers per tussock; NLPT, number of leaves per tussock; NDF, neutral detergent fibre; ADF, acid detergent fibre; Ca, calcium; P, phosphorus; *F*, *F*-value; *p*, *p*-value.

UR had significantly more tillers (+12.7) and leaves (+141.2) than CG ($p < 0.001$; Table 3). Across years and harvests, UR produced 32.2% more biomass and 38.4% more crude protein (CP) than CG ($p < 0.001$). By contrast, CG had lower concentrations of CP (−19.4%), metabolisable energy (ME, −23.4%), and ash (−22.7%), but higher fibre fractions (NDF and ADF) and phosphorus (P) (all $p < 0.001$).

Table 3. Main effect of grass species and harvest times on morphological characters, yields, and nutritional concentrations.

Variables	Grass Species		Harvest Times		
	UR	CG	1	2	3
Number of tillers per tussock	24.2 a	11.5 b	20.5	22.5	17.4
Number of leaves per tussock	185.2 a	44.0 b	121.3	139.5	123.9
Biomass yield, t/ha DM	12.4 a	8.4 b	12.5 b	13.9 a	9.2 c
Crude protein yield, t/ha	1.3 a	0.8 b	1.1	1.3	1.1
Crude protein, g/kg DM	96.1 a	77.4 b	82.4 c	94.1 b	111.2 a
Metabolisable energy, MJ/kg DM	13.2 a	10.1 b	9.5 c	13.6 a	11.9 b
Neutral detergent fibre, g/kg DM	546.8 a	619.4 b	678.3 a	663.8 a	633.3 b

Table 3. *Cont.*

Variables	Grass Species		Harvest Times		
	UR	CG	1	2	3
Acid detergent fibre, g/kg DM	326.0 b	377.0 a	422.6 a	410.3 a	362.5 b
Ash, g/kg DM	60.2 a	46.5 b	56.9 c	57.4 b	64.7 a
Calcium, g/kg DM	2.8	2.7	2.5 c	3.0 b	3.5 a
Phosphorus, g/kg DM	1.3 b	1.8 a	1.6 b	1.8 a	2.0 a

Means with different lowercase letters within a row differ significantly ($p < 0.05$). Abbreviations: UR, *Urochloa ruziziensis*; CG, *Chloris gayana.*

Harvest effects were also present. Biomass yields peaked at harvest 2 and were lowest at harvest 3 ($p < 0.001$). CP concentration increased over time, being 9.2% higher at harvest 2 and 25.8% higher at harvest 3 relative to harvest 1 ($p < 0.001$). ME concentration followed a similar pattern, reaching 13.6 MJ/kg DM at harvest 2 and dropping to 9.5 MJ/kg DM at harvest 1 ($p < 0.001$). Fibre fractions (NDF, ADF) declined from harvests 1 to 3, while ash, Ca, and P increased ($p < 0.001$).

The interactions among year, harvest, and grass species for NTPT and NLPT are visualised in Figure 3. Across all years, harvest 2 consistently recorded higher NLPT and NTPT in each grass species. A significant year × harvest interaction ($p = 0.040$, Table 2) was observed for NLPT, with the highest mean value in harvest 2 of 2020 (157.7) and the lowest in harvest 3 of 2019 (109.5).

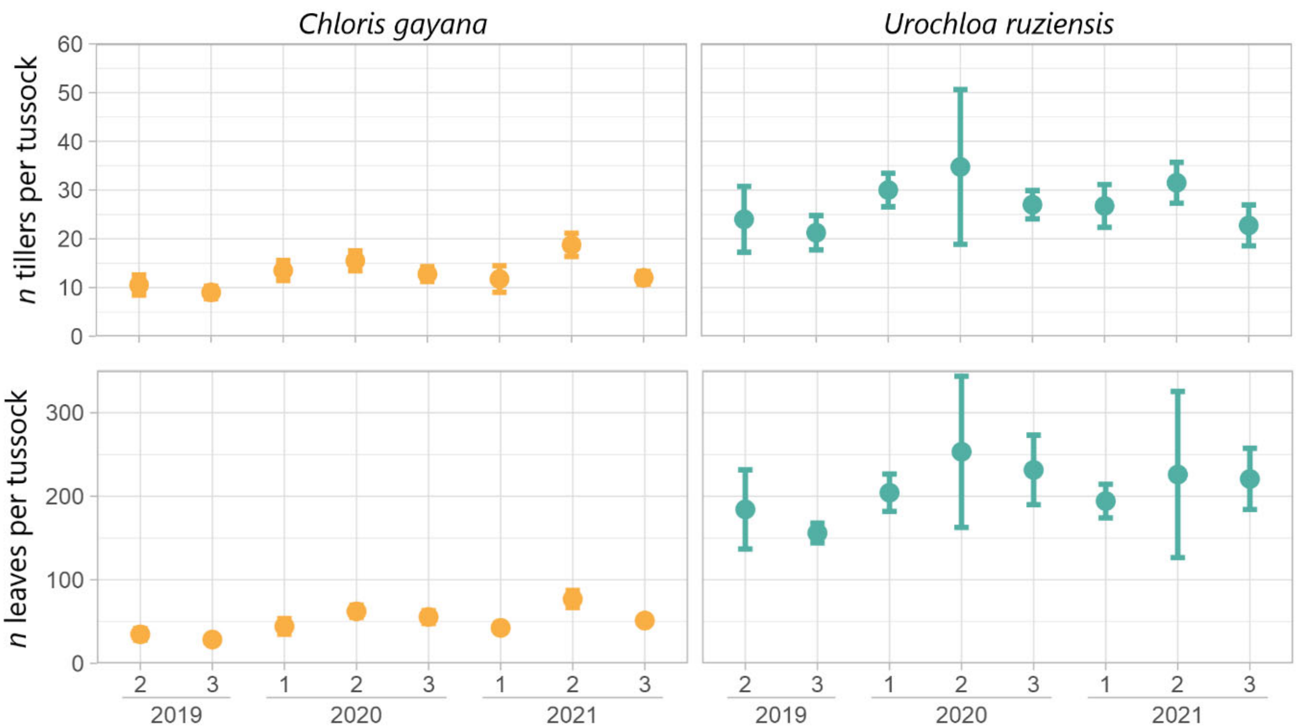

Figure 3. Number (*n*) of tillers and leaves per tussock from two harvests (2 and 3) in 2019 and three harvests (1, 2, and 3) in 2020 and 2021 of *Urochloa ruziensis* (green) and *Chloris gayana* (orange) Points represent the mean and error bars represent 95% bootstrapped confidence intervals.

Similarly, biomass, CP, and ME yields were higher in harvest 2 of 2020 in both grass species (Figure 4). A significant year × harvest interaction was observed for biomass yield ($p = 0.045$), with the maximum yield recorded in harvest 3 of 2019 (16.8 t DM/ha) and the minimum in harvest 3 of 2019 for CG (8.33 t DM/ha). Similarly, CP yield was significantly affected ($p = 0.034$, Table 2), peaking in harvest 2 of 2020 (1.61 t DM/ha) and reaching the lowest value in harvest 3 of 2021 (0.91 t DM/ha). ME yield followed the same trend as CP yield, with highest yield in harvest 2 of 2020 and lowest in harvest 3 of 2019 for CG ($p = 0.027$).

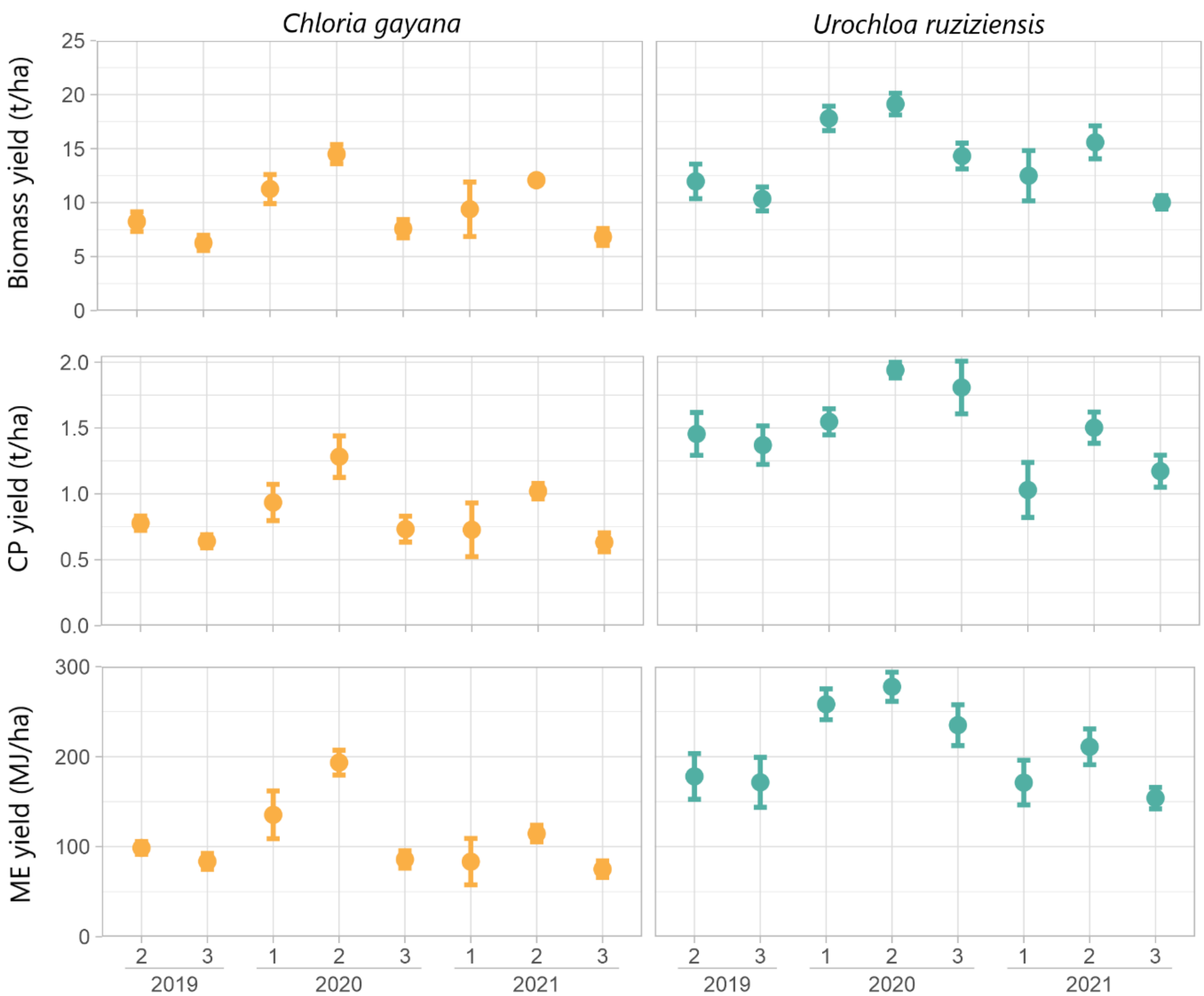

Figure 4. Biomass, crude protein (CP), and metabolisable energy (ME) yields from two harvests (2 and 3) in 2019 and three harvests (1, 2, and 3) in 2020 and 2021 of *Urochloa ruziziensis* (green) and *Chloris gayana* (orange). Points represent the mean and error bars represent 95% bootstrapped confidence intervals.

The ME, CP, and Ca concentrations consistently increased from harvest 1 to 3, while fibre components (NDF and ADF) decreased from harvest 1 to 3 over the same period in both grasses across all three years (Figure 5). Significant interactions were detected for CP concentration between year × harvest and grass species × harvest ($p = 0.001$). The highest CP concentration (111.3 g/kg DM) occurred in harvest 3 of 2020, whereas the lowest (79.9 g/kg DM) was recorded in harvest 1 of 2021. In the grass species × harvest interaction, CP concentration in harvest 3 of UR was 35.9% higher than the lowest value (80.2 g/kg DM) observed in harvest 1 of CG. Across years, UR consistently showed lower NDF and ADF concentrations than CG, with both fibre components declining from harvest 1 to 3 within each species.

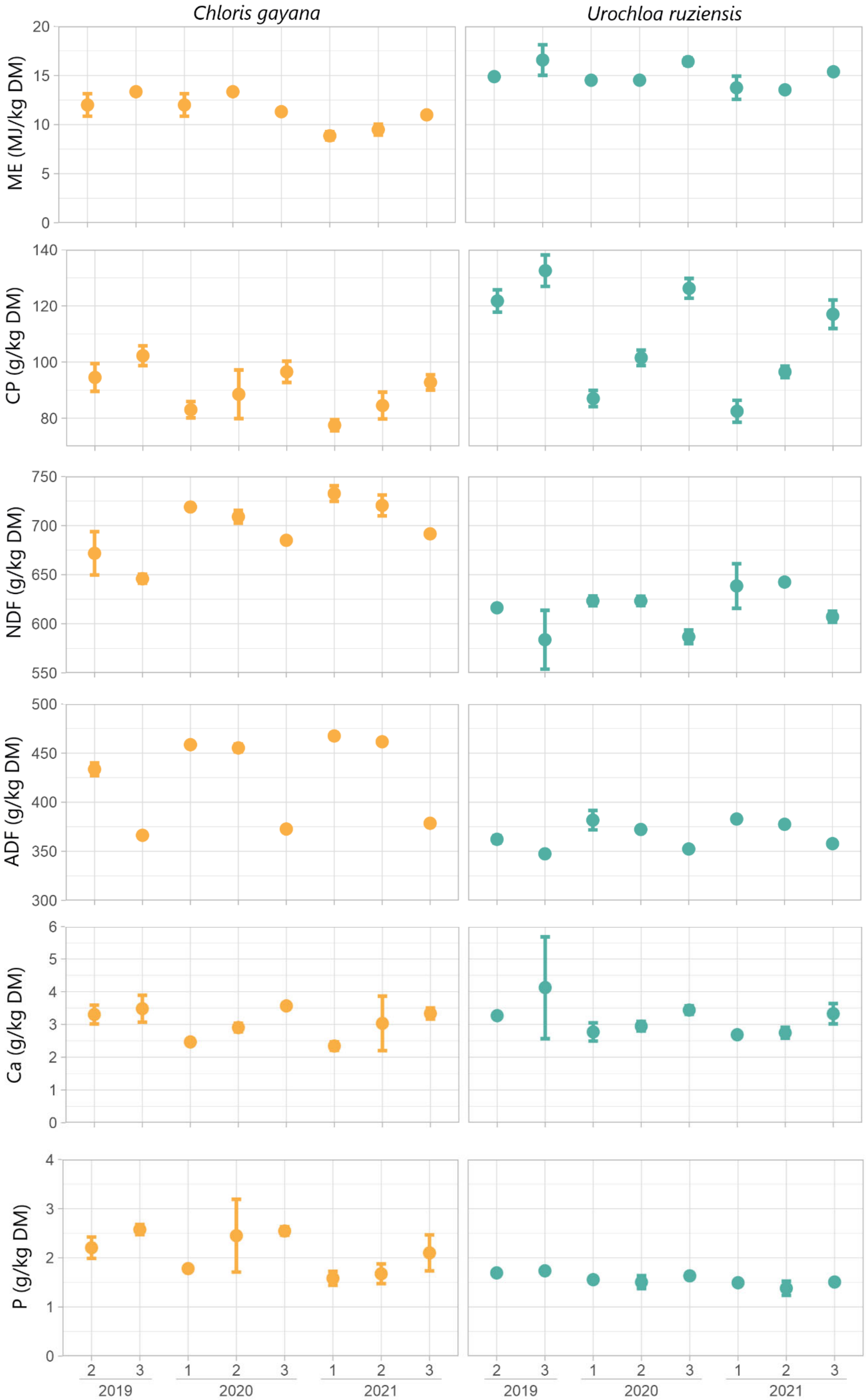

Figure 5. Metabolisable energy (ME), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), calcium (Ca), and phosphorus (P) concentrations from two harvests (2 and 3) in 2019 and three harvests (1, 2, and 3) in 2020 and 2021 of *Urochloa ruziziensis* (green) and *Chloris gayana* (orange). Points represent the mean and error bars represent 95% bootstrapped confidence intervals.

In 2020 and 2021, CG recorded the highest values for NDF (714.8, $p < 0.001$) and ADF (235.8 g/kg DM; $p = 0.043$), respectively, compared to the other year × harvest averages (Table 2). Notably, a significant grass species × harvest interaction ($p < 0.001$, Table 2) was observed in harvest 1 of CG (462.9 g/kg DM) and was lowest in harvest 3 of UR for ADF.

Calcium concentration was significantly influenced by harvest ($p < 0.001$), with higher values in later harvests, but showed no significant differences between species, years, or their interactions (Table 2). In contrast, phosphorus concentration was significantly affected by species, harvest, and their interaction ($p < 0.001$), with generally higher values in CG than in UR and an overall increase from harvest 1 to 3 (Table 2).

4. Discussion

4.1. Morphological Characters and Yield

Smallholder livestock farmers in Sub-Saharan African countries, including Nigeria, often face low animal productivity due to inadequate feed resources. This study was conducted in Nigeria's Northern Guinea savanna region to investigate the yields and quality of UR and CG as potential feed source options for farmers. UR has consistently outperformed CG across all harvests, producing higher yields of biomass, CP, and ME compared to CG. Additionally, UR also exhibited a higher density of tillers and leaves per tussock, underscoring its potential as a superior forage resource for small livestock farmers in the region.

Numerous studies have demonstrated that tiller number is a critical determinant of forage grass yield [32–36]. Our findings support this, as UR consistently produced more tillers than CG, which likely contributed to its higher biomass across all harvests and years. Nonetheless, biomass production is also influenced by factors such as management practices, variety, and the environment. Leaves generally contain more protein and less cell wall content than stems, making them more digestible. The greater leaf number in UR may therefore explain its higher concentration of CP compared to CG. Differences in tiller and leaf numbers between grasses are largely attributed to genetic and species factors, as reported in previous studies [36–40]. Both grass species persisted throughout the three-year study without stand loss, demonstrating good adaptation to the Northern Guinea Savanna environment. However, UR maintained a denser tiller and leaf population than CG, reflecting stronger persistence under repeated cutting. These findings suggest that UR may offer greater long-term stand stability for cut-and-carry systems in this region.

4.2. Nutrient Concentrations

The quality of forage strongly influences feed intake, growth, grazing behaviour, and reproduction of ruminants, which, in turn, determines the economic returns, yield, and quality of livestock products [41,42]. Among quality attributes, CP concentration is one of the most critical indicators and is essential for ruminant nutrition [34]. The higher CP concentration observed in UR may suggest superior forage quality compared to CG. Previous studies have shown that later harvests can increase CP, energy, and ash while decreasing fibre content [21,34,43], a trend consistent with our findings. This may be attributed to the regrowth of young tissues following defoliation, which typically have higher nutritional value [44–46]. The lower fibre concentrations in UR are likely due to its higher leaf proportion relative to CG, since leaves generally contain less fibre than stems and other structural plant parts [47].

In a meta-analysis, Jayasinghe et al. [48] reported the average nutrient and digestibility of tropical grass species, representing 56 tropical pasture species and hybrid cultivars grown in 26 different tropical environments across 16 countries. In this present study, the average CP value of UR (9.61%) was slightly lower than the *Urochloa* genus average (10.9%) reported in that meta-analysis, whereas the CP of CG (8.93%) was notably lower than the *Chloris* genus average (10.1%). For fibre fractions, the average NDF and ADF concentrations of CG were higher than the reported tropical averages of 67.3% and 38.8%, respectively. *Chloris* species are known to have greater ADF concentrations than most tropical species [48], and our findings are consistent with this, as the ADF value for CG (42.4%) exceeded the general tropical species mean (38.8%) but was comparable to the Chloris genus mean. Differences between our values and those reported for other *Urochloa* and *Chloris* species can be attributed to genotypic variation [49], whereas the divergence of CG values from the broader tropical species averages is more likely attributed to species-specific responses to management practices and environmental factors [50].

The significant Year × Species interaction effects observed for CP, ME, NDF, ADF, and P concentrations indicate that the relative performance of UR and CG varied across years. This highlights the influence of inter-annual weather fluctuation, such as rainfall distribution and temperature shifts, on the nutrient dynamics of the two species. Rainfall was highest in 2019 and lowest in 2021, which likely contributed to the progressive decline in CP and the corresponding increase in fibre fractions (NDF and ADF) over the three years. Abundant rainfall in 2019 may have supported vigorous vegetative growth with higher leaf protein, whereas the drier conditions in 2021 promoted slower regrowth, accumulation of structural carbohydrates, and dilution of protein. Despite this trend, UR consistently maintained higher CP and ME and lower fibre fractions than CG across years, demonstrating greater resilience to seasonal rainfall variation. In contrast, CG exhibited sharper reductions in CP and larger increases in fibre, suggesting that its nutritive value is more sensitive to inter-annual climatic variation. Overall, these findings emphasise that while both grasses show quality deterioration with stand age and rainfall decline, UR sustains superior forage quality and stability, making it a more reliable option under variable climatic conditions.

4.3. Implications for Tropical Ruminant Production

According to the findings of this study, under a three-harvest management system (following a two-harvest establishment year), UR can support a greater number of animals than CG. This is evident from the higher biomass production (+21%) and CPY (+35%) for UR compared to CG, suggesting that UR can support a greater number of animals than CG. The concentrations of CP in the two grass species were above 8%, necessary for adequate body maintenance and rumen microbial synthesis [51], provided other rumen environmental factors are optimal. In terms of protein adequacy, the CP levels in both grass species can meet the 9–10% required for tropical breeds and crossbred bulls, steers, and heifers for body maintenance [52]. Although UR could occasionally meet the 10–12% CP threshold required by dry tropical dairy cows (e.g., 11.1% at harvest 3), neither UR nor CG met the 14–16% requirement during lactation as outlined by Moran [53]. These findings highlight the necessity of protein supplementation to support milk production and animal health when UR and CG serve as the primary feed resource for ruminants in this region.

Several studies [43,50,54] have reported that NDF concentrations exceeding 60% restrict forage intake and consistently reduce livestock productivity. In this present study, CG exhibited an average NDF value of 71.5% (≈11.5 percentage points above the 60% threshold), while UR averaged 63% (3 percentage points above the threshold). These results indicate that both grasses may limit voluntary intake, with CG likely posing a greater negative effect on animal performance.

Mineral elements are crucial for the growth, reproduction, and overall health of livestock, and deficiencies in dietary supply can reduce productivity. Ca and P are particularly important for bone and tooth development and other physiological functions [55]. In this study, Ca concentrations in the two forage species ranged from 2.8 to 3.5 g/kg DM, consistent with typical values for tropical forages [56]. However, these levels were slightly below the recommended range of 0.38–0.8% for small ruminants in the tropics [57]. In contrast, P concentrations were substantially lower than the 0.25–40% required to sustain growth and normal physiological functions in small ruminants, as outlined by Rashid [57]. Moreover, tropical breeds and crossbred bulls, steers, and heifers, on the other hand, generally require even higher concentrations of Ca (4.4–5.34 g/kg DM) and P (2.2–2.92 g/kg DM) [58]. Given the grass management system applied in this study, the mineral concentrations observed in both species were below these recommended thresholds. Therefore, animals relying solely on the two grass species would likely require mineral supplementation (e.g., block licks) or inclusion of other feeds richer in minerals to achieve optimal productivity.

5. Conclusions

This study evaluated the biomass production and nutritive value of UR and CG under cut-and-carry management in the Northern Guinea Savanna of Nigeria. UR consistently outperformed CG in biomass and CP yields and metabolisable energy, indicating its potential to support greater livestock productivity. However, the average CP concentration in UR (9.6%) fell below the 10–12% requirement for dry tropical dairy cows and only reached this threshold in specific harvests, while neither grass met the 14–16% requirement during lactation. In addition, NDF concentrations in both grasses exceeded the 60% threshold that can restrict intake, with CG posing a greater limitation. Furthermore, P concentrations and, in some cases, Ca were below recommended levels for ruminant growth and physiological functions. These findings indicate that UR surpasses CG in productivity and nutritive value, but the practical utility of both grasses is limited by inadequate protein at key physiological stages and by mineral deficiencies. Therefore, incorporating protein-rich forages or supplements alongside mineral licks is essential to optimise livestock performance when these grasses serve as primary feed resources in this region.

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Abbreviations

The following abbreviations are used in this manuscript:

CG	*Chloris gayana*
UR	*Urochloa ruziziensis*
CP	crude protein
SSA	Sub-Saharan Africa

N	nitrogen
P	phosphorus
Ca	calcium
ME	metabolisable energy
NTPT	number of tillers per tussock
NLPT	number of leaves per tussock
NDF	neutral detergent fibre
ADF	acid detergent fibre
DM	dry matter
g	gram
kg	kilogramme

References

1. Robinson, T.; Pozzi, F. *Mapping Supply and Demand for Animal-Source Foods to 2030*; FAO Animal Production and Health Working Paper No. 2; FAO (Food and Agriculture Organization of the United Nations): Rome, Italy, 2011. Available online: https://www.fao.org/4/i2425e/i2425e00.htm (accessed on 12 January 2023).
2. Cooke, A.S.; Machekano, H.; Gwiriri, L.C.; Tinsley, J.H.I.; Silva, G.M.; Nyamukondiwa, C.; Safalaoh, A.; Morgan, E.R.; Lee, M.R.F. The Nutritional Feed Gap: A Review of Seasonal Variation in Ruminant Forage Availability and Quality in Southern Africa. *SSRN* **2024**. [CrossRef]
3. Tolera, A.; Abebe, A. Livestock production in pastoral and agro–pastoral production systems of Southern Ethiopia. *Livest. Res. Rural Develop.* **2007**, *19*, 177. Available online: http://www.lrrd.org/lrrd19/12/tole19177.htm (accessed on 23 October 2024).
4. Jimoh, S.O.; Muraina, T.O.; Bello, S.K.; Eldeen, N.N. Emerging issues in grassland ecology research: Perspectives for advancing grassland studies in Nigeria. *Acta Oecol.* **2020**, *106*, 103548. [CrossRef]
5. Chapman, D.F.; Mackay, A.D.; Caradus, J.R.; Clark, D.A.; Goldson, S.A. Pasture productivity in New Zealand 1990–2020: Trends, expectations, and key factors. *N. Z. J. Agric. Res.* **2025**, *68*, 1221–1264. [CrossRef]
6. Valle, C.B.; Jank, L.; Resende, R.M.S. Tropical forage breeding in Brazil. *Revist. Ceres* **2009**, *56*, 460–472. [CrossRef]
7. Simeão, R.M.; Resende, M.D.V.; Alves, R.S.; Pessoa-Filho, M.; Azevedo, A.L.S.; Jones, C.S.; Pereira, J.F.; Machado, J.C. Genomic Selection in Tropical Forage Grasses: Current Status and Future Applications. *Front. Plant Sci.* **2021**, *12*, 665195. [CrossRef]
8. Heuzé, V.; Tran, G.; Boval, M.; Maxin, G.; Lebas, F. Congo Grass (*Brachiaria ruziziensis*). Feedipedia, a Programme by INRAE, CIRAD and FAO. 2017. Available online: https://www.feedipedia.org/node/484 (accessed on 4 March 2024).
9. Schultze-Kraft, R.; Teitzel, J.K. Brachiaria ruziziensis Germain & Evrard. In *Record from Proseabase*; Mannetje, L.'t, Jones, R.M., Eds.; PROSEA (Plant Resources of South-East Asia) Foundation: Bogor, Indonesia, 1992.
10. ILRI. *Ruzi Grass (*Brachiaria ruziziensis*) for Livestock Feed on Small-Scale Farms*; International Livestock Research Institute: Nairobi, Kenya, 2013; ILRI Forage Facts Sheet; Available online: https://hdl.handle.net/10568/2339 (accessed on 25 August 2024).
11. Cook, B.G.; Pengelly, B.C.; Brown, S.D.; Donnelly, J.L.; Eagles, D.A.; Franco, M.A.; Hanson, J.; Mullen, B.F.; Partridge, I.J.; Peters, M.; et al. *Tropical Forages: An Interaction Selection Tool. Web Tool*. CSIRO, DPI&F(Qld), CIAT, ILRI, Brisbane, QLD, Australia. 2005. Available online: https://hdl.handle.net/10568/49072 (accessed on 19 December 2023).
12. Husson, O.; Charpentier, H.; Razanamparany, C.; Moussa, N.; Michellon, R.; Naudin, K.; Razafintsalama, H.; Rakotoarinivo, C.; Rakotondramanana; Séguy, L. *Brachiaria* sp., *B. ruziziensis*, *B. brizantha*, *B. decumbens*, *B. humidicola*. In *Manuel pratique du semis direct à Madagascar*; CIRAD: Paris, France, 2008; Volume III, Chapter 3, Part 4.1; Available online: https://agris.fao.org/search/en/providers/122653/records/6473697c53aa8c89630dafd7 (accessed on 9 October 2025).
13. Santana, J.C.S.; Ítavo, L.C.V.; Ítavo, C.C.B.F.; Dias, A.M.; Niwa, M.V.G.; Moraes, G.J.; Arcanjo, A.H.M.; Gurgel, A.L.M.; Borges, A.D.; Formigoni, G.M.; et al. Productive characteristics, chemical composition, in vitro digestibility, and degradation kinetics of two *Brachiaria* grasses at different regrowth ages. *Trop. Anim. Health Prod.* **2022**, *54*, 342. [CrossRef]
14. Ponsens, J.; Hanson, J.; Schellberg, J.; Moeseler, B.M. Characterisation of phenotypic diversity, yield and response to drought stress in a collection of Rhodes grass (*Chloris gayana* Kunth) accessions. *Field Crops Res.* **2010**, *118*, 57–72. [CrossRef]
15. Imaz, J.A.; Giménez, D.O.; Grimoldi, A.A.; Striker, G.G. Ability to recover overrides the negative effects of flooding on growth of tropical grasses *Chloris gayana* and *Panicum Coloratum*. *Crop Pasture Sci.* **2015**, *66*, 100–106. [CrossRef]
16. Heuzé, V.; Tran, G.; Boudon, A.; Lebas, F. Rhodes Grass (*Chloris gayana*). Feedipedia Programme by INRAE, CIRAD, AFZ and FAO. 2016. Available online: https://www.feedipedia.org/node/480 (accessed on 5 July 2024).
17. Murphy, S. Tropical Perennial Grasses—Root Depths, Growth and Water Use Efficiency. NSW Industry and Investment, Primefacts N° 1027; 2008. Available online: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/343695/Tropical-perennial-grasses-root-depths-growth-and-water-use-efficiency.pdf (accessed on 17 April 2024).

18. Jayasinghe, P.; Donaghy, D.J.; Barber, D.G.; Pembleton, K.G.; Ramilan, T. Suitability evaluation of three tropical pasture species (Mulato II, Gatton Panic, and Rhodes Grass) for Cultivation under a subtropical Climate of Australia. *Agronomy* **2022**, *12*, 2032. [CrossRef]
19. Daba, A.W.; Qureshi, A.S.; Nisaren, B.K. Evaluation of Some Rhodes Grass (*Chloris gayana*) Genotypes for Their Salt Tolerance, Biomass Yield and Nutrient Composition. *Appl. Sci.* **2019**, *9*, 143. [CrossRef]
20. Kawamura, K.; Watanabe, N.; Sakanoue, S.; Inoue, Y. Estimating forage biomass and quality in a mixed sown pasture based on partial least squares regression with waveband selection. *Grassl. Sci.* **2008**, *54*, 131–145. [CrossRef]
21. Akpensuen, T.T. Defoliation frequencies of forage legumes: Effects on yield and nutritive value for beef cattle production. *Sumerianz J. Agric. Vet.* **2022**, *5*, 6–13. [CrossRef]
22. FAO. The Future of Livestock in Nigeria. Opportunities and Challenges in the Face of Uncertainty. Rome. 2019. Available online: https://www.fao.org/documents/card/ru/c/ca5464en/ (accessed on 8 June 2023).
23. UN. *World Population Prospects. Key Findings and Advance Tables*; United Nations: New York, NY, USA, 2017. Available online: https://population.un.org/wpp/assets/Files/WPP2017_KeyFindings.pdf (accessed on 7 March 2024).
24. Olowolafe, E.A.; Dung, J.E. Soils derived from biotite-granites on the Jos Plateau, Nigeria: Their nutrient status and management for sustainable agriculture. *Resour. Conserv. Recycl.* **2000**, *29*, 231–244. [CrossRef]
25. Karki, U. Forage definition and classification. In *Sustainable Year-Round Forage Production and Grazing/BrowsingManagement for Goats in the Southern Region. Handbook for Training Field Extension and Technical Assistance Personnal*; Karki, U., Ed.; Tuskegee University Extension Programme: Tuskegee, AL, USA, 2013; pp. 3–12. Available online: https://southern.sare.org/resources/sustainable-year-round-forage-production-and-grazing-browsing-management-in-the-southern-region/ (accessed on 2 September 2023).
26. Nancy, J.T.; Harold, M.; Shirley, A.; Jan-Åke, P. Determination of Crude Protein in Animal Feed, Forage, Grain, and Oilseeds by Using Block Digestion with a Copper Catalyst and Steam Distillation into Boric Acid. *J. AOAC Int.* **2002**, *85*, 309–317. [CrossRef]
27. Van Soest, P.J.; Robert, J.B.; Lewis, B.A. Method for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **1991**, *74*, 3583–3597. [CrossRef]
28. Nancy, T.; Lawrence, N.; Andy, C. Determination of Ash in Animal Feed: AOAC *Official Method* 942.05 Revisited. *J. AOAC Intl.* **2012**, *95*, 1392–1397. [CrossRef]
29. Heckman, M. Minerals in Feeds by Atomic Absorption Spectrophotometry. *J. AOAC* **1967**, *50*, 45–50. [CrossRef]
30. Chen, H.; Xiong, F.; Wu, Q.; Wang, W.; Cui, Z.; Zhang, F.; Wang, Y.; Lv, L.; Liu, Y.; Bo, Y.; et al. Estimation of Energy Value and Digestibility and Prediction Equations for Sheep Fed with Diets Containing Leymus chinensis Hay. *Agriculture* **2023**, *13*, 1213. [CrossRef]
31. R Core Team R. *A Language and Environment for Statistical Computing*; R. Foundation for Statistical Computing: Vienna, Austria, 2023; Available online: https://www.R-project.org (accessed on 17 May 2024).
32. Volenec, J.J.; Cherney, J.H.; Johnson, K.D. Yield components, plant morphology, and forage quality of alfalfa as influenced by plant population1. *Crop Sci.* **1987**, *27*, 321–326. [CrossRef]
33. Alzueta, I.; Abeledo, L.G.; Mignone, C.M.; Miralles, D.J. Differences between Wheat and Barley in Leaf and Tillering Coordination under Contrasting Nitrogen and Sulfur Conditions. *Eur. J. Agron.* **2012**, *41*, 92–102. [CrossRef]
34. Li, T.; Peng, L.; Wang, H.; Zhang, Y.Y.; Cheng, Y.; Hou, F. Multi-Cutting Improves Forage Yield and Nutritional Value and Maintains the Soil Nutrient Balance in a Rainfed Agroecosystem. *Front. Plant Sci.* **2022**, *13*, 825117. [CrossRef] [PubMed]
35. Akpensuen, T.T.; Namo, O.A.T. Establishment yield and nutrient composition of four legumes as influenced by age of growth in a cool tropical climate at Jos, Plateau State, Nigeria. *Trop. Grassl.* **2023**, *11*, 83–94. [CrossRef]
36. Ojong, N.; Takor, M.; Egbe, A.; Bechem, E.; Etchu, K.; Mutai, C. The effect of cutting regime and genotype on growth, seed yield, seed quality and herbage yield of seven Urochloa (syn. Brachiaria) grass genotypes in the Adamawa region of Cameroon. *Grassl. Sci.* **2024**, *70*, 77–92. [CrossRef]
37. Wassie, W.A.; Tsegay, B.A.; Wolde, A.T.; Limeneh, B.A. Evaluation of morphological characteristics, yield and nutritive value of Brachiaria grass ecotypes in northwestern Ethiopia. *Agric. Food Secur.* **2018**, *7*, 89. [CrossRef]
38. Oesterheld, M.; Loreti, J.; Semmartin, M.; Sala, O.E. Inter-annual variation in primary production of a semi-arid grassland related to previous-year production. *J. Veg. Sci.* **2001**, *12*, 137–142. [CrossRef]
39. Li, F.Y.; Snow, V.O.; Holzworth, D.P. Modelling the seasonal and geographical pattern of pasture production in New Zealand. *N. Z. J. Agr. Res.* **2011**, *54*, 331–352. [CrossRef]
40. Kim, M.; Chemere, B.; Sung, K. Effect of Heavy Rainfall Events on the Dry Matter Yield Trend of Whole Crop Maize (*Zea mays* L.). *Agriculture* **2019**, *9*, 75. [CrossRef]
41. Waterman, R.C.; Grings, E.E.; Geary, T.W.; MacNeil, M.D. Influence of seasonal forage quality on glucose kinetics of young beef cows. *J. Anim. Sci.* **2007**, *85*, 2582–2595. [CrossRef]
42. Zhang, Q.; Bell, L.W.; Shen, Y.; Whish, J.P.M. Indices of forage nutritional yield and water use efficiency amongst spring-sown annual forage crops in north-west China. *Eur. J. Agron.* **2018**, *93*, 1–10. [CrossRef]

43. Gilo, B.N.; Tolossa, A.R.; Tebeje, B.E.; Liban, J.D. Changes in herbaceous vegetation attributes and nutritional quality as influenced by cutting frequencies in the enclosure of Borana rangelands, southern Ethiopia. *Ecol. Indic.* **2022**, *145*, 109672. [CrossRef]
44. Cop, J.; Vidrih, M.; Hacin, J. Influence of cutting regime and fertilizer application on the botanical composition, yield and nutritive value of herbage of wet grasslands in Central Europe. *Grass Forage Sci.* **2009**, *64*, 454–465. [CrossRef]
45. Inyang, U.; Vendramin, J.M.B.; Sellers, B.; Silveira, M.L.A.; Lunpha, A.; Sollenberger, L.E.; Adesogab, A. Harvest frequency and stubble height affect herbage accumulation, nutritive value, and persistence of "Mulato II," Brachiariagrass. *Forage Graz. Land.* **2010**, *8*, 1–7. [CrossRef]
46. Yang, T.H.; Cheng, H.; Eun, J.K.; Chang, S.H.; Zhang, Y.; Ben-Tian, M.; Hou, F. Responses of high-sugar ryegrass productive performance to stimulated grazing on the loess plateau. *Pral. Sci.* **2015**, *32*, 1473–1481. [CrossRef]
47. Lee, M.A. A global comparison of the nutritive values of forage plants grown in contrasting environments. *J. Plant Res.* **2011**, *131*, 641–654. [CrossRef]
48. Jayasinghe, P.; Ramilan, T.; Donaghy, D.J.; Pembleton, K.G.; Barber, D.G. Comparison of Nutritive Values of Tropical Pasture Species Grown in Different Environments, and Implications for Livestock Methane Production: A Meta-Analysis. *Animals* **2022**, *12*, 1806. [CrossRef]
49. Boval, M.; Edouard, N.; Sauvant, D. A meta-analysis of nutrient intake, feed efficiency and performance in cattle grazing on tropical grasslands. *Anim. Consort. J.* **2015**, *9*, 973–983. [CrossRef]
50. Van Soest, P.J. *Nutritional Ecology of the Ruminant*, 2nd ed.; Cornell University Press: Ithaca, NY, USA, 1994.
51. Osuga, I.M.; Abdulrazak, S.A.; Muleke, C.I.; Fujihara, T. Effect of supplementing Rhodesgrass hay (*Chloris gayana*) with *Berchemia discolor* or *Zizyphusmucronata* on the performance of growing goats in Kenya. *Anim. Physiol. Anim. Nutr.* **2011**, *96*, 634–639. [CrossRef]
52. Rotta, P.P.; Menezes, A.C.B.; Costa e Silva, L.F.; Valadares Filho, S.D.C.; Prados, L.F.; Marcondes, M.I.; Gionbelli, M.P.; Chizzotti, M.L. Protein requirements for beef cattle. In *BR—Corte: Nutrient Requirements of Zebu and Crossbred Cattle*; Filho, S.C.V., Silva, L.F.C., Gionbelli, M.P., Rotta, P.P., Marcondes, M.I., Chizzotti, M.L., Prados, L.F., Eds.; Suprema Gráfica Ltda: Camacan, Brazil, 1994; pp. 185–212. [CrossRef]
53. Moran, J. *Tropical Dairy Farming: Feeding Management for Smallholder Dairy Farmers in the Humid Tropics*; Csiro Publishing: Collingwood, VIC, Australia, 2005; pp. 51–59. Available online: www.landlinks.com.au (accessed on 3 October 2024).
54. Meissner, H.H.; Koster, H.H.; Nieuwoudt, S.H.; Coetze, R.J. Effects of energy supplementation on intake and digestion of early and mid-season ryegrass and Panicum/Smuts finger hay, and on in sacco disappearance of various forage species. *S. Afr. J. Anim. Sci.* **1991**, *21*, 33–42.
55. Ravhuhali, K.E.; Mudau, H.S.; Mokoboki, H.K.; Moyo, B.; Motsei, L.E. Effect of harvesting site on mineral concentration of browse species found in semi-arid areas of South Africa. *J. Saudi Soc. Agric. Sci.* **2023**, *22*, 165–173. [CrossRef]
56. Freer, M.; Dove, H.; Nolan, J.V. *Nutrient Requirements of Domesticated Ruminants*; CSIRO Publishing: Melbourne, VIC, Australia, 2007. Available online: https://www.scribd.com/document/910627702/Nutrient-Requirements-of-Domesticated-Ruminants-Csiro-instant-access-2025 (accessed on 15 October 2023).
57. Rashid, M. *Goats and Their Nutrition*; Manitoba Goat Association: Winnipeg, MB, Canada, 2008. Available online: https://extension.msstate.edu/publications/mineral-requirements-and-impact-dairy-and-meat-goat-production (accessed on 8 June 2024).
58. Silva, L.F.C.; Filho, S.C.V.; Rotta, P.P.; Marcondes, M.I.; Zanetti, D.; Gionbelli, M.P.; Engle, T.E.; Paulino, M.F. Mineral requirements for beef cattle. In *BR—Corte: Nutrient Requirements of Zebu and Crossbred Cattle*; Filho, S.C.V., Silva, L.F.C., Gionbelli, M.P., Rotta, P.P., Marcondes, M.I., Chizzotti, M.L., Prados, L.F., Eds.; Suprema Gráfica Ltda: Camacan, Brazil, 2016; pp. 213–249. [CrossRef]